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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H05B 3/00, 3/06, 3/34, 3/54

A1

(11) International Publication Number: WO 98/01009

(43) International Publication Date: 8 January 1998 (08.01.98)

(21) International Application Number: PCT/US97/11253

(22) International Filing Date: 27 June 1997 (27.06.97)

(30) Priority Data:
08/673,920 1 July 1996 (01.07.96) US

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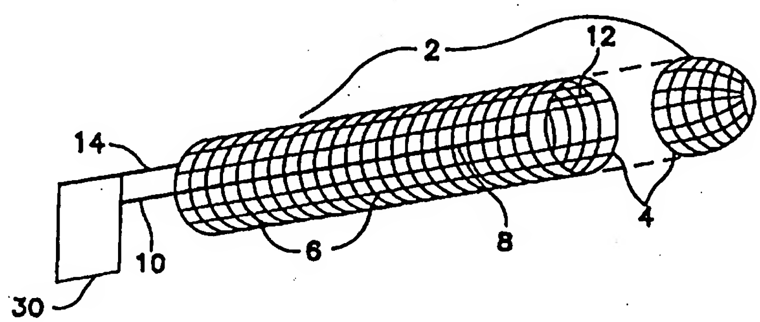
(81) Designated States: CA, JP, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

(54) Title: ELECTRICALLY-HEATED, FLEXIBLE AND STRETCHABLE, SHAPED FABRIC



(57) Abstract

This invention discloses an electrically-heated, flexible and stretchable, shaped fabric (2). The invention specifically discloses a circuit device that is interlaced with textile fibers (6) to form a textile material (4). The textile material can be shaped into fabrics of any desired contour.

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ELECTRICALLY-HEATED, FLEXIBLE AND STRETCHABLE, SHAPED FABRIC

Background of the Invention

The present invention relates to an electrically-heated, flexible and stretchable, textile material that can be formed into shaped fabrics of any desired contour comprising a circuit device that is interlaced with the fibers that make up the textile material. In this context, interlaced is defined to mean knitted, twisted, woven, nonwoven, tufted, embroidered and the like. Examples of the present invention are described in detail in the form of an electrically-heated, flexible and stretchable, knitted textile material made into a tubular shape and a glove. By using these examples, the invention is not meant to be limited to these electrically-heated, flexible and stretchable, shaped fabrics, but it is intended to include all fabric shapes that can be manufactured using this textile material.

The following patent summaries are indicative of the prior art.

In U.S. Patent No. 5,484,983, there is disclosed an electric heating element of a knit fabric that includes current supply wires and resistance wires which are incorporated into the heating element. This knit fabric covers, but does not enclose, the areas to be heated, thereby having four edges. The current supply wires and resistance wires extend mutually substantially perpendicularly in the heating element with the each of the ends of the resistance wires being interlaced with each of the two conducting wires. The conductive wires may be disposed in local or edge regions spaced apart with the knit fabric located therebetween. The knit fabric

located between the conductive wires may be formed of non-conductive fibers or resistance wires whose number determines the heating power available and thus the heating characteristics of the knit fabric.

In U.S. Patent No. 5,422,462, there is disclosed conductive yarns and conductive wires having insulated properties at least on their surfaces that are plain-woven as warps and wefts, thus manufacturing a unidirectional conductive fabric in which neighboring conductive yarns are not electrically in contact with each other. A pair of electrodes is connected to ends of the conductive yarn, and polymeric insulating layers are laminated on both surfaces of the unidirectionally conductive fabric, thus manufacturing an electric heating sheet. Moreover, by forming polymeric covering layers having a thermal fuse function, a temperature-directing function, and a temperature-controlling function on the unidirectional conductive fabrics, highly durable and safe electric heating sheets are manufactured.

In U.S. Patent No. 4,983,814, there is disclosed a fibrous heating element having an electrical resistance of 1 to 100 ohms per meter that is prepared by coating a core fiber, preferably a yarn, with one or more electroconductive layers consisting of a polyurethane resin having carbon particles dispersed therein. The fibrous element is pliable and can be knit or woven into a fabric, and is particularly suitable for use in an electric heating blanket or in an industrial heating element.

In U.S. Patent No. 4,764,665, there is disclosed a heated glove that includes an electrically heated woven fabric in which the fabric has been coated with electri-

cally conducting metal to enable its use as a heating element. The fabric heating element is in the shape of the front and back of a hand with the front and back being electrically connected together only at the tips of the fingers, and it is disposed between inner and outer insulating fabric layers.

In U.S. Patent 3,781,514, there is disclosed an electrically heated glove having a flexible lattice structure of plastic material having an electrical heater wire embedded therein and extending continuously in adjacent lengths along the length of said lattice structure. The electrical heater wire having a plurality of heater wire loops extending from said lattice structure and interconnecting said adjacent lengths of said heater wire for the application of electric current thereto.

In U.S. Patent 975,359, there is disclosed an electric heater consisting of a fabric into which is incorporated a filament that contains a wire to conduct electricity that is surrounded by an insulation material. This constructed filament is heated by the passage of a current and it is incorporated into successive transverse sections of the fabric.

These prior art devices are not exhaustive, but are exemplary of the state of the art. While such prior art devices provide some improvement within the areas specified in their disclosures, there still exists a need for a circuit device that is interlaced with a textile material to form an electrically-heated, flexible and stretchable, shaped fabric that encloses or engulfs the object to be heated and overcomes the disadvantages of the prior art while having utility features that provide

new and useful advantages and improvements not heretofore disclosed.

Electrically heated textile materials are helpful in combatting the effects of cold temperatures and severe weather on individuals subject to prolonged exposure to these temperatures and weather. These materials can be used either as coverings for exposed objects and individuals or as actual clothing for individuals who are frequently exposed to cold temperatures and severe weather for prolonged periods of time.

The prior art devices that have been designed to warm an exposed individual have the disadvantage of not being both flexible and stretchable. Because these devices can only be stretched in one direction, it is difficult to construct shaped fabrics from them, particularly when a cylindrical or sharply curved shape is required. In fact, attempts to make such clothing from them has resulted in the deterioration and breakage of the included insulated fibers that are used as heating elements. As a result, heated textile materials have been largely limited to fabric coverings with little or no curvature and multiple edges. Also, these prior art devices employ electrical conductors at their edges, resulting in further flexibility-related difficulties in making the small cylindrical shapes necessary to design garments to cover individuals and protect them from cold temperatures, including breakage and short-circuiting of the electrical conductors.

Additionally, the prior art devices employ wires or metal strips that have been insulated, either individually or as a whole, to heat the fabric. They are often not interlaced with the fabric material. As a result of

the insulation and these configurations, heat builds-up and is then difficult to dissipate. This results in the temperature of the fabric being difficult to stabilize and consequent poor temperature control.

Alternatively, some prior art devices do have circuit devices interlaced with the fabric material. However, these devices depend upon varying the number and characteristics of the interlaced resistance and conductive wires as the method used to optimize the heating capabilities of the fabric. This results in additional complexities during manufacture and causes difficulties in maintaining appropriate temperature control when some of the resistance wires of the electric heating circuit are damaged or destroyed during the normal, anticipated use of the fabric.

Accordingly, the principle object of the present invention is to provide a new and improved circuit device that is interlaced into an electrically-heated, flexible and stretchable, textile material that is easily shaped into generally tubular fabrics of small diameter. Another object of the present invention is to provide new and improved uninsulated, flexible and stretchable, high resistance fibers interlaced with the textile material so as to heat the textile material when connected to a knitted conductive wire network. Yet another object of the present invention is the production of a knitted fabric containing the circuit device that is resistant to breakage or short-circuiting of the included circuit device and the consequent deterioration of its heating capabilities. Still another object of the present invention is to provide an electrically-heated, flexible and stretchable, shaped fabric wherein uniform heating and ease of temperature control are

achieved by variation in the electrical current supplied to and the characteristics of the high resistance fibers of the current device and the temperature is measured by sensors that allow feedback control of the electrical current supplied. A further object of the present invention is to provide an electrically-heated, flexible and stretchable, shaped fabric wherein the current is supplied to the high resistance fibers and returned to the power source by at least two conductive wires. A still further object of the present invention is to achieve the above objects with an essentially simple structure that lends itself to inexpensive mass-production.

Summary of the Invention

The invention described herein is a circuit device that is interlaced with textile fibers to form an electrically-heated, flexible and stretchable, textile material that can be made into shaped fabrics of any desired contour. The circuit device itself is made of uninsulated, partially conductive, high resistance fibers that act as heating elements and are interlaced in a flexible and stretchable textile material in such a way that the characteristics of these high resistance fibers are also flexible, thereby avoiding their breakage or deterioration and consequent loss of heating capabilities. These resistance fibers have a higher electrical resistance than the two conductive wires that are also interlaced in a flexible and stretchable textile structure. The high resistance fibers are interlaced across the lengths of the conductive wires.

The structure of the interlaced circuit is designed such that the two conductive wires are placed substantially parallel to each other, vertically interlaced,

and spaced equidistantly from each other within the shaped fabric when viewed in cross-section, thus avoiding short-circuiting. The high resistance fibers form a grid or mesh that is placed between these conductive wires in a substantially perpendicular fashion, again avoiding short-circuiting. The high resistance fibers are interlaced with the conductive wires within the textile material. Each individual high resistance fiber is formed into a continuous tubular structure. As a result of the structure of the interlaced circuit, the pathway along each high resistance fiber running from the first conductive wire to the second conductive wire is substantially the same distance as the pathway running from the second conductive wire back to the first conductive wire, thus making the resultant electrical circuits substantially equivalent.

The conductive wires can also be attached at one of their ends to a knitted wire network. This knitted wire network comprises conductive wires that are knitted together and make electrical contact at the junctions of the wire network, thus making a knitted circuit board that is flexible and stretchable and interlaced into the textile material. This knitted wire network can be made up of conductive wires that run in the horizontal weft direction and the vertical wale direction and make electrical contact at their junctions, thus being able to conduct electrical current from a power source to the circuit device that is interlaced with textile fibers to form the flexible and stretchable textile material. The wires running in the horizontal weft direction and the vertical wale direction can make electrical contact at their intersections by physical interlacing, resistive welding or soldering, or other methods of connection. This knitted wire network is essentially analogous to a

circuit board with the added benefit of flexibility, in essence, making it a knitted, flexible circuit board. Additionally, the temperature of the space enclosed or engulfed by the electrically-heated, flexible and stretchable, shaped fabric can be controlled by a temperature-sensing semiconductor with a feedback control system with the semiconductor being placed in the circuit at a place convenient for sensing temperature.

The interior spaces thus enclosed or engulfed by these shaped fabrics can be heated to a pre-determined temperature by virtue of the interlaced circuit device. The heating capabilities of these shaped fabrics are controlled by the characteristics of the wires of the circuit device and by variation in the electrical current supplied to these wires using sensors that allow feedback control of the electrical current supplied, thus regulating the temperature. When connected to a power source, uniform heating and ease of temperature control can be achieved in the electrically-heated, flexible and stretchable, shaped fabrics of this invention. The present invention can be employed to manufacture heated, shaped fabrics of many uses in a cost-efficient manner that lends itself readily to mass-production techniques.

By preparing electrically-heated, flexible and stretchable, shaped fabrics in such a manner, the previously noted problems of deterioration, breakage, and short-circuiting of the high resistance fibers and conducting wires of the interlaced circuit device and the overall rigidity of fabrics of the prior art are overcome. In addition, the circuit device of this invention does not require the use of insulated wires as in the prior art. Its use of these uninsulated, flexi-

ble fibers and wires and the dependence of its heating capabilities on the electrical current supplied, as regulated by the feedback control system described and the fiber characteristics rather than the number of wires included in the fabric, results in improved temperature stability of the shaped fabric which leads to better temperature control. These characteristics of the circuit device interlaced with textile fibers that forms an electrically-heated, flexible and stretchable, shaped fabric described herein make this invention into one with multiple advantages over the prior art.

Other objects, features, and advantages will be apparent from the following detailed description of preferred embodiments taken in conjunction with the accompanying drawings in which:

Brief Description of the Drawings

Fig. 1 is an enlarged perspective view of an electrically-heated, flexible and stretchable, shaped fabric constructed in accordance with the principles of the present invention that has been formed into a tubular shape.

Fig. 2 is a top view of an alternative embodiment of the electrically-heated, flexible and stretchable, shaped fabric constructed in accordance with the principles of the present invention that has been formed into a glove.

Detailed Description of Preferred Embodiments

Fig. 1 illustrates an electrically-heated, flexible and stretchable, shaped fabric 2 formed into a tubular shape. The electrically-heated, flexible and stretchable, shaped fabric 2 includes the textile fibers knit-

ted to form a textile material 4. Into this textile material 4 is interlaced the mutually substantially parallel and vertically interlaced high resistance fibers 6 that heat the textile material 4 and warm the enclosed three-dimensional tubular shape. The two conductive wires 8 and 12 that conduct current to the mutually substantially parallel and vertically interlaced high resistance fibers 6 are interlaced into the textile material 4 such that the conductive wires 8 and 12 are substantially perpendicular to the mutually substantially parallel and vertically interlaced high resistance fibers 6, which, in turn, are interlaced between the conductive wires 8 and 12. The conductive wires 8 and 12 have ends 10 and 14 that are attached to a power supply 30 that provides the current to the interlaced mutually substantially parallel and vertically interlaced high resistance fibers 6 which allows heating of the textile material 4 and warming of the enclosed tubular space.

Fig. 2 illustrates an alternative embodiment of the invention in which the electrically-heated, flexible and stretchable, shaped fabric is formed into a glove 20. The top view of a right-hand glove is illustrated. As in Figure 1, the mutually substantially parallel and vertically interlaced high resistance fibers 6 are placed substantially perpendicular to the conductive wires 8 and both types of wires are interlaced into the textile material 4. In this embodiment, five tubular sections each containing a heating electrical circuit are shown. These five sections correspond to the five fingers of a glove.

The conductive wires 8 from each tubular finger section are connected by additional conductive wires 22

that form a knitted wire network made up of conductive wires that are knitted together and make electrical contact at the junctions of the wire network, thus making a knitted circuit board that is flexible and stretchable and interlaced into the textile material. This knitted wire network can be made up of conductive wires that run in the horizontal weft direction and the vertical wale direction and make electrical contact at their junctions, thus being able to conduct electrical current from a power source 30 to the circuit device that is interlaced with textile fibers to form the flexible and stretchable textile material. The wires running in the horizontal weft direction and the vertical wale direction can make electrical contact at their intersections by physical interlacing, resistive welding or soldering, or other methods of connection. This knitted wire network is essentially analogous to a circuit board with the added benefit of flexibility, in essence, making it a knitted, flexible circuit board. Additionally, the temperature of the space enclosed or engulfed by the electrically-heated, flexible and stretchable, shaped fabric can be controlled by temperature-sensing semiconductors with a feedback control system 32 placed in each finger of the glove. The knitted conductive wire network 22 has ends 10 and 14 that are attached to a power supply 30 that provides the current to the interlaced mutually substantially parallel and vertically interlaced high resistance fibers 6 through the conductive wires 8 and 12, which allows heating of the textile material 4 and warming of the enclosed tubular spaces into which the fingers fit.

It will now be apparent to those skilled in the art that other embodiments, improvements, details, and uses can be made consistent with the letter and spirit of the

foregoing disclosure and within the scope of this patent, which is limited only by the following claims, construed in accordance with the patent law, including the doctrine of equivalents.

What is claimed is:

1. An electrically-heated, flexible and stretchable, shaped fabric comprising:

(a) a plurality of textile fibers knitted into a textile material, said textile material formed into a plurality of shapes that enclose three-dimensional spaces to be heated,

(b) a plurality of high resistance, uninsulated fibers that are flexible and are substantially mutually parallel to each other and vertically interlaced into the textile material,

(c) a first lower resistance, uninsulated, conductive wire that is flexible and is interlaced into the textile material in a manner substantially perpendicular to the mutually substantially parallel and vertically interlaced high resistance, uninsulated fibers such that one end of the first lower resistance, uninsulated, conductive wire can be attached to an anode of a power supply and the mutually substantially parallel and vertically interlaced high resistance, uninsulated fibers are interlaced across the length of the first lower resistance, uninsulated, conductive wire, and

(d) a second lower resistance, uninsulated, conductive wire that is flexible and stretchable that is interlaced into the textile material in a manner substantially perpendicular to the mutually substantially parallel and vertically interlaced high resistance, uninsulated fibers such that one end of the second lower resistance, uninsulated, conductive wire can be attached to a cathode of a power supply and the mutually substantially parallel and vertically interlaced high resistance, uninsulated wires are interlaced along the length of the second lower resistance, uninsulated, conductive wire and such that the second lower resistance, uninsulated, conductive wire is placed in the textile material in a manner that a pathway along each high resistance,

uninsulated fiber running from the second lower resistance, uninsulated, conductive wire to the first lower resistance, uninsulated, conductive wire is substantially the same distance as a pathway along each high resistance, uninsulated fiber running from the first lower resistance, uninsulated, conductive, wire back to the second lower resistance, uninsulated, conductive wire, thus making the second lower resistance, uninsulated, conductive wire is substantially equidistant from the first lower resistance, uninsulated, conductive wire.

2. An electrically-heated, flexible and stretchable, shaped fabric comprising:

(a) a plurality of textile fibers knitted into a textile material, said textile material formed into a plurality of shapes that enclose three-dimensional spaces to be heated,

(b) a plurality of high resistance, uninsulated fibers that are flexible and are substantially mutually parallel to each other and vertically interlaced into the textile material,

(c) a first lower resistance, uninsulated, conductive wire that is flexible and is interlaced into the textile material in a manner substantially perpendicular to the mutually substantially parallel and vertically interlaced high resistance, uninsulated fibers such that one end of the first lower resistance, uninsulated, conductive wire can be attached to a first knitted wire network and the mutually substantially parallel and vertically interlaced high resistance, uninsulated fibers are interlaced across the length of the first lower resistance, uninsulated, conductive wire,

(d) a second lower resistance, uninsulated, conductive wire that is flexible and stretchable that is

interlaced into the textile material in a manner substantially perpendicular to the mutually substantially parallel and vertically interlaced high resistance, uninsulated fibers such that one end of the second lower resistance, uninsulated, conductive wire can be attached to a second knitted wire network and the mutually substantially parallel and vertically interlaced high resistance, uninsulated wires are interlaced along the length of the second lower resistance, uninsulated, conductive wire and such that the second lower resistance, uninsulated, conductive wire is placed in the textile material in a manner that a pathway along each high resistance, uninsulated fiber running from the second lower resistance, uninsulated, conductive wire to the first lower resistance, uninsulated, conductive wire is substantially the same distance as a pathway along each high resistance, uninsulated fiber running from the first lower resistance, uninsulated, conductive, wire back to the second lower resistance, uninsulated, conductive wire, thus making the second lower resistance, uninsulated, conductive wire is substantially equidistant from the first lower resistance, uninsulated, conductive wire,

(e) a first and second knitted wire network, each made of conductive wires that are knitted together and make electrical contact at the junctions of said wire network, thus making a knitted circuit board with the knitted circuit board being flexible and stretchable and interlaced into the textile material with the first knitted wire network connected at one end to the first, lower resistance, uninsulated, conductive wire and at the second end to the anode of a power supply and with the second knitted wire network connected at one end to the second lower, resistance, uninsulated, conductive wire and at the second end to the cathode of a power

supply, and

(f) a temperature-sensing semiconductor with a feedback control system, said temeperature-sensing semiconductor connected into the circuit device interlaced with the textile fibers that forms the electrically-heated, flexible and stretchable, shaped fabric that encloses the space whose temperature is controlled by said semiconductor.

3. A knitted wire network comprising conductive wires that are knitted together and make electrical contact at the junctions of said wire network, thus making a knitted circuit board with the knitted circuit board being flexible and stretchable and interlaced into a textile material.

4. The electrically-heated, flexible and stretchable, shaped fabric of claim 1, wherein said electrically-heated, flexible and stretchable, shaped fabric is formed into a finger of a glove.

5. The electrically-heated, flexible and stretchable, shaped fabric of claim 1, wherein said electrically-heated, flexible and stretchable, shaped fabric is formed into a glove.

6. The electrically-heated, flexible and stretchable, shaped fabric of claim 1, wherein said electrically-heated, flexible and stretchable, shaped fabric is formed into enclosures for various portions of the body.

7. The electrically-heated, flexible and stretchable, shaped fabric of claim 1, wherein said electrically-heated, flexible and stretchable, shaped fabric is used to heat portions of the body.

8. The electrically-heated, flexible and stretchable, shaped fabric of claim 2, wherein said electrically-heated, flexible and stretchable, shaped fabric is formed into a finger of a glove.

9. The electrically-heated, flexible and stretchable, shaped fabric of claim 2, wherein said electrically-heated, flexible and stretchable, shaped fabric is formed into a glove.

10. The electrically-heated, flexible and stretchable, shaped fabric of claim 2, wherein said electrically-heated, flexible and stretchable, shaped fabric is formed into enclosures for various portions of the body.

11. The electrically-heated, flexible and stretchable, shaped fabric of claim 2, wherein said electrically-heated, flexible and stretchable, shaped fabric is used to heat portions of the body.

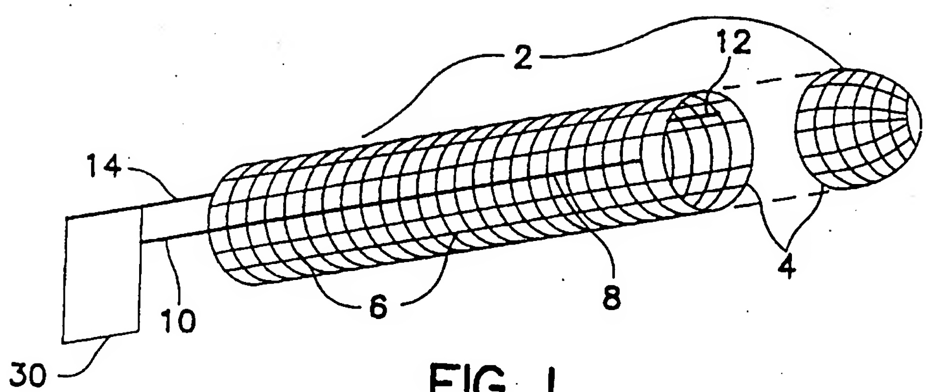

FIG. 1

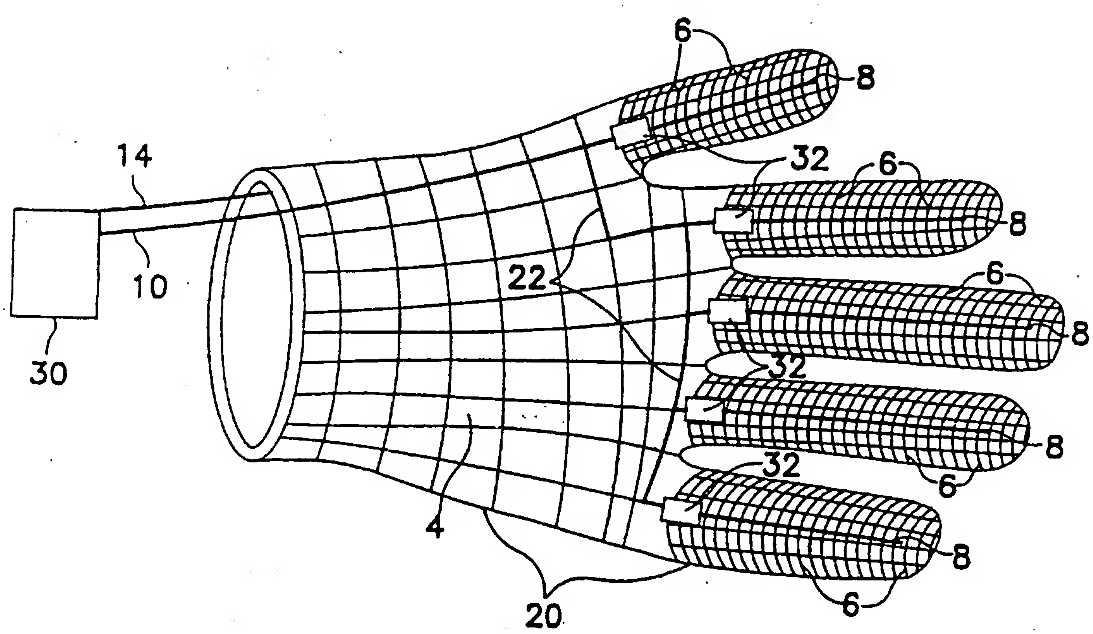

FIG. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/11253

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H05B 3/00, 3/06, 3/34, 3/54
US CL :219/211, 527, 528, 529, 545
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 219/211, 527, 528, 529, 545

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Please See Extra Sheet.

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 5,298,722 A (TANAKA) 29 MARCH 1994, SEE ENTIRE DOCUMENT, ESPECIALLY COLUMN 2, LINES 26-54.	1 ---------- 2, 4-11
X ---- Y	US 3,349,359 A (MOREY) 24 OCTOBER 1967, SEE ENTIRE DOCUMENT, ESPECIALLY COLUMN 3, LINES 39-61.	1 ---------- 2, 4-11
X ----- Y	US 3,721,799 A (CARLSTROM) 20 MARCH 1973, SEE ENTIRE DOCUMENT, ESPECIALLY COLUMN 2, LINES 4-18.	3 --------- 2, 4-11
Y	US 5,422,462 A (KISHIMOTO) 06 JUNE 1995, SEE COLUMN 6, LINES 10-34.	2, 4-11
A	US 5,484,983 A (ROELL) 16 JANUARY 1996, SEE COLUMN	1-11

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
08 AUGUST 1997	09 OCT 1997

Name and mailing address of the ISA/US	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/11253

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4,983,814 A (OHGUSHI ET AL) 08 JANUARY 1991, SEE COLUMN 3, LINES 17-28.	1-11
A	US 4,764,665 A (ORBAN ET AL) 16 AUGUST 1988, SEE COLUMN 2, LINES 5-16.	4-11
A	US 3,781,514 A (OLSON ET AL) 25 DECEMBER 1973, SEE COLUMN 1, LINES 34-41.	4-11
A	MCCORMACK ET AL, TESTING OF ELECTRICALLY HEATED GLOVES FOR COLD ENVIRONMENTS. SAE. JULY, 1995, PAPER SERIES 951547, SEE ENTIRE DOCUMENT.	4-11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/11253

B. FIELDS SEARCHED
Documentation other than minimum documentation that are included in the fields searched:

MCCORMACK, AC AND WEBBON, BW. (1995) TESTING OF ELECTRICALLY HEATED GLOVES FOR COLD ENVIRONMENTS. SAE TECHNICAL PAPER SERIES 951547.